How to build a high gain vertical antenna for the UHF amateur or CB bands

You can use low-cost coaxial cable to make a simple, high performance, omnidirectional vertical antenna that is ideal for both home station and portable applications.

THE collinear antenna has been around a long time. Various versions enjoyed popularity on the amateur VHF and UHF bands in the eras before and after World War II. But the collinear fell out of favour when the Yagi array became popular since the late '50s. The Yagi's popularity is attributable to its feature of giving the 'best bang for the buck'. But it is a beam which requires rotating.

With the rise in popularity of FM operation on the VHF and UHF bands since the '70s, the proliferation of commercial amateur rigs, and the development of repeater networks around the country, the demand for omnidirectional antennas grew apace. A lot of FM activity is mobile, with a degree of base or home station operation, too. For the latter application, an omnidirectional antenna with gain offers distinct advantages, particularly where comparatively low-powered mobile rigs are used at home.

The growth of UHF CB has followed a similar path, boosted by the availability of locally-manufactured transceivers selling alongside imports. Open access repeaters helped the growth of UHF CB, too.

A home-constructed antenna can save you big bucks. Many constructors make up a simple *groundplane* or *coaxial dipole*, which have the advantage of simplicity. However, something that offers a respectable amount of gain and can be assembled with little more effort is a bonus.

The collinear antenna to be described offers considerable gain and improved bandwidth over the conventional groundplane, coaxial dipole, 'Slim Jim' or similar antennas. It is simple to construct and erect since it does not require tuning or pruning, and uses cheap, commonly available 'quarter-inch' RG58 coax.

The word collinear means 'in line', the elements of the collinear antenna being placed in line, end to end. Two half wave dipoles placed end to end and fed out of phase make the simplest two-element collinear.

A collinear from coax

To make a collinear antenna from coaxial cable, a number of elements, each an *electrical* half wavelength long, are joined together with the inner conductor and the shield braid transposed at each joint, as illustrated in Figure 1. An even number of elements is required. By transposing the coax's inner and outer conductors at each join, each half wave element is fed out of phase.

I first ran across this form of the collinear in a scientific publication in the early '70s. The published paper described a *monstrous*, 400 metre long, 104 element array used for a

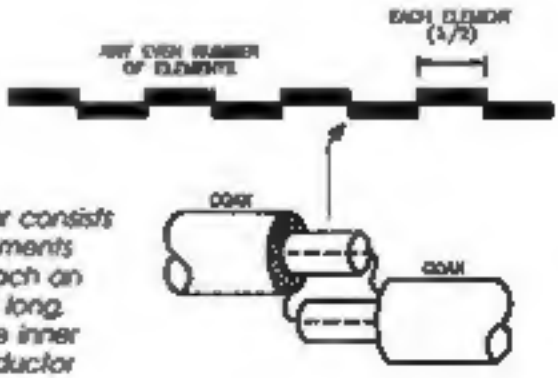

Figure 1. A coaxial collinear consists of an even number of elements made of coaxial cable, each an electrical half wavelength long, joined end to end with the inner conductor and outer conductor transposed at each joint.

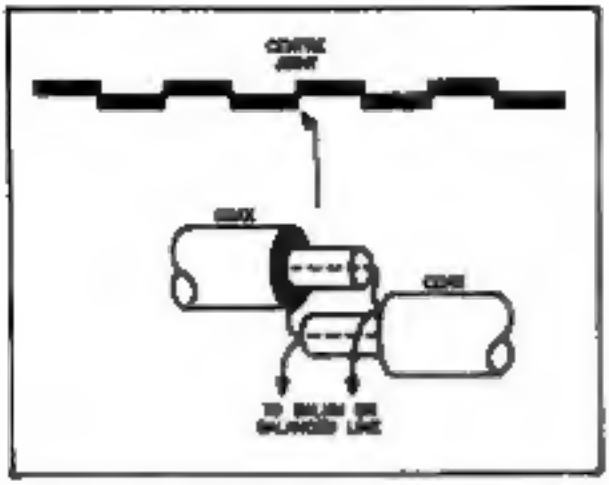

Figure 2. Coaxial collinears may be fed at the centre, as illustrated here, or at the end, which is used in the antenna described (see Figure 3).

50MHz radar located at Jicamarca in Peru, used for probing the ionosphere. The beamwidth of this wonder was reported to be just one degree!

The number of elements used determines the gain, beamwidth and bandwidth of a coaxial collinear antenna. The gain increases by 3dB every time you double the number of elements. Two elements provides a gain of 3dB compared to a dipole, four elements would give 6dB, eight elements 9dB, etc.

For the technically inclined, the bandwidth is generally defined as the point at which the gain degrades due to phase variations greater than one-sixth pi radians on the end elements. You can calculate the bandwidth from:

bandwidth = 2f/(3n + 1)

where 'f' is the centre frequency of operation, and 'n' is the number of elements in the array.

The interesting thing is, if you use lossy coax, the antenna's performance improves without markedly decreasing the gain or increasing the beamwidth. Hence the use of common-or-garden RG58!

Feeding It

You have two opportunities to connect a feedpoint to the coaxial collinear – in the middle, or in the end. When centre fed, the feedline is connected across the centre joint, as illustrated in Figure 2.

As you may already appreciate, this is a balanced connection and requires a balanced line or a balun transformer to connect unbalanced coaxial feedline. The feedpoint impedance is a few hundred ohms, allowing the use of a simple 4:1 balun.

But feeding a collinear in the middle is awkward when you want to mount it vertically. The feedline must come away from the array at right angles. So, feeding it from the bottom is the solution, and you get a direct match to 50 ohm coax!

However, you can't just connect the coax to the end of the array. The radiation from the elements will couple onto the outer conductor (shield braid) of the coax and you get a 'hot' line. There are various ways to overcome this, but one of the simplest to implement is the addition of two groundplane elements at right angles, a quarter wavelength below the feedpoint. These groundplane elements, just like those on a conventional quarterwave groundplane, are a few per cent longer than a half wavelength tip-to-tip. You can use more than two if you wish.

Making It

This is one of my favourite do-it-yourself antennas as it's easily made, is not critical on dimensions, needs no tuning adjustments, matches directly to 50 ohm coax and goes together in quick-smart time. You can buy all the bits and make it in less than a day and have it on the air the same evening.

The general arrangement and dimensions of an 8-element coaxial collinear array are shown in Figure 3. The dimensions shown put the antenna's centre frequency on 436.5MHz for the 70cm amateur band; the dimensions in brackets put the antenna's centre frequency on 476.9MHz, the middle of the UHF CB band. This makes the array of a size which is readily handled – about two metres tall for the 70cm version, and about 1.8 metres tall for the UHF CB version.

There are two band segments 'reserved' on the 70cm amateur band for FM simplex and repeater operation, these being 433.025-434.975MHz and 438.025-439.975MHz. Thus, 436.5MHz is in the middle.

As I said earlier, each element is an electrical half wavelength long. That is,

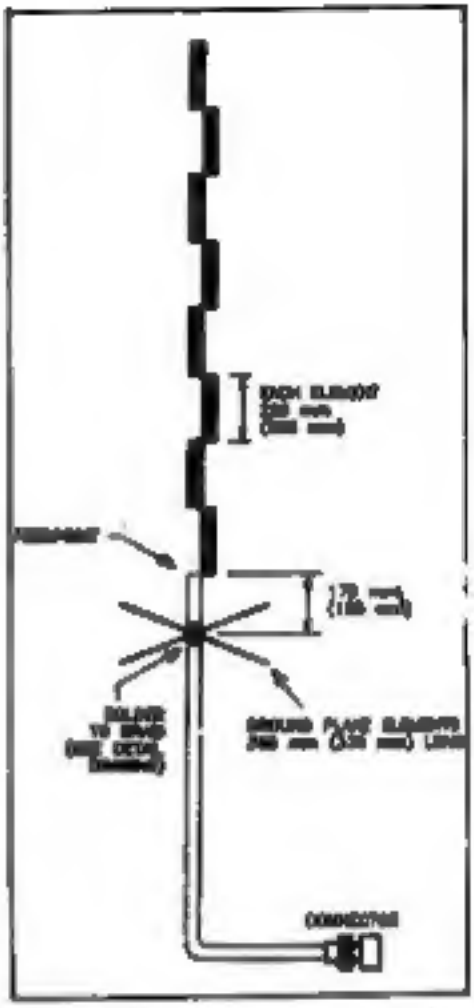

Figure 3. The general form of the UHF coaxial collinear antenna described. Dimensions are shown for the 70cm amateur band and the UHF CB band (in brackets).

the velocity factor of the coax must be taken into account. As electromagnetic energy travels slower in the dielectric of the coaxial cable, a wavelength is physically shorter. The velocity factor of common RG58 is approximately 0.65-0.66.

It is fortunate that the bandwidth of the collinear is quite broad – about 35MHz, or around 8 per cent – as this allows plenty of tolerance in the dimensions. Around plus/minus 5mm actually.

Buy three metres of RG58CU coax and get good quality cable, such as one with a 'MIL-C-17F' specification (it's often referred to as 'RG58CU Commercial'). Retailers such as Dick Smith Electronics, Captain Communications and Emtronics carry suitable RG58. In addition, you will need 500mm of 9.5mm or 12.7mm diameter heatshrink tubing and about 50mm of 6.4mm heatshrink.

As you would appreciate, the collinear is not self-supporting; it's distinctly floppy. To hold it up, attach it

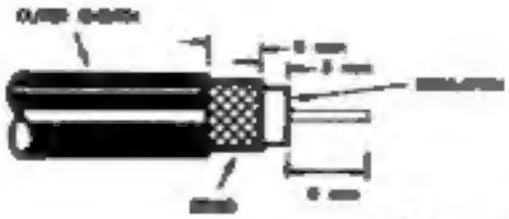

Figure 4. Each element is cut from a piece of RG58 50 ohm coaxial cable and the ends prepared like this.

to any non-conducting support. Dowelling rod from your local hardware store is great for this job and it comes in standard two metre lengths, which is just right. Choose 12.7mm or 19mm diameter dowel, to suit yourself.

Now, go through the following procedure step by step and you'll find your collinear goes together quite easily.

1) The very first thing to do is prepare the collinear's support, using a 12.7mm or 19mm diameter wooden dowel rod. This is cheap, readily available and strong enough for the job. The dowel should be thoroughly sealed with an outdoor wood stain or linseed oil, paying particular attention to the ends. Stand it aside to dry properly.

2) Now for the collinear itself. The 'working' length of each element is the distance between the ends of the braid. To simplify matters, and to allow for the odd error, cut eight lengths of RG58, each 250mm long for the 70cm amateur band, or 230mm long for the UHF CB band. These lengths make allowance for cutting and stripping back the ends of the elements to make the joints.

3) Prepare each end of seven elements, and only one end of the eighth element, as detailed in Figure 4. The eighth element will become the 'top' element of the antenna.

Cut the coax's outer sheath 16mm back from the end using a blunt penknife or hobby knife. It should be blunt so as to avoid nicking the shield braid here. *Do not* unravel the shield braid.

4) Now cut the braid, this time using a sharp knife, 8mm back from the end. Take care not to cut through the dielectric to the centre conductor. Combined use of a sharp knife and sharp, pointed sidecutters can be effective and result in a neat cut.

5) Next, cut back the dielectric 8mm back from the end to expose the centre conductor. Do this carefully so you don't nick the stranded centre conductor wires. Otherwise, later you may get a break in the centre conductor, or a stray strand may short the joint. Either way, your antenna won't work properly.

6) With the ends of all the elements prepared as per Figure 4, now tin the exposed centre conductor and shield braid on each. Use a hot iron, preferably a temperature controlled type. A flat-faced ('spade') tip is best for this job. Apply the tip to the part to be tinned for a few seconds to heat it, then apply the solder. Use thin gauge, resin-cored solder. But remember to only apply enough solder to lightly 'wet' the conductors.

7) Now to solder the elements together. First slip a 35-40mm length of 9.5mm or 12.7mm diameter heatshrink on each element. Solder the elements together, end to end, as shown in Figure 5. With each joint, after it has cooled, apply silicone sealant to the area of the joint to seal it, then, while the silicone is still plastic, slip the heatshrink tubing over the joint and apply a blast of hot air (hair dryers are great for this). But don't overdo the hot air, though, or you're likely to soften the outer sheath of the coax and possibly damage it.

8) The top element needs to be sealed. Apply a dab of silicone sealant to it, slip on a 30-40mm length of 6.4mm heatshrink, while it's still soft, then apply a short blast of hot air to shrink it in place.

9) The next step is to attach what you've just completed to its support. Plastic zip-up cable ties are great for this, as are the plastic zip-lock ties that come with packets of garbage bags. Tie the collinear to the dowel, starting with the top element, putting a tie either side of each joint. The top element should be tied about 50mm below the top end. The other elements should be near the joints.

While the collinear should be laid straight when tying it to the dowel, don't apply too much tension to avoid fracturing the soldering at the joints. Don't depend on the heatshrink for mechanical support, its prime purpose is protection.

10) Now for the feedpoint and groundplane. You'll have a short length of RG58 left over. Attach a suitable in-line connector, such as a BNC male, to one end and prepare the other end as per Figure 4.

Measure back along the cable, from the end of the shield braid, a quarter wavelength (this time, 'free space' wavelength). For the 70cm amateur band, this is 190mm; for the UHF CB band, 185mm. Mark this point.

Using a blunt knife, or carefully using a sharp knife, make two cuts around the cable's outer sheath, each a few millimetres either side of this point. Slit the sheath between the two cuts and remove the section to expose the shield braid. Using a hot iron, quickly and lightly tin the braid. Slip two 30-40mm lengths of 6.4mm diameter heatshrink down the cable, placing them either side of the exposed shield braid.

11) Cut two lengths of tinned copper wire or brazing rod to size: each 360mm long for the 70cm amateur band, and 330mm long for the UHF CB band (see Figure 3). If you're using tinned copper wire, straighten it first. This can be done by clamping one end in a vise, grasping the other end with a pair of pliers and giving it a good tug. It will bow a bit after you take it out of the vise, but then you can straighten it easily by hand. Tin the centre of each groundplane element.

12) Now attach the prepared cable to the feedpoint, making a joint as per Figure 5. Seal it and cover it with heatshrink. Put a tie either side of the

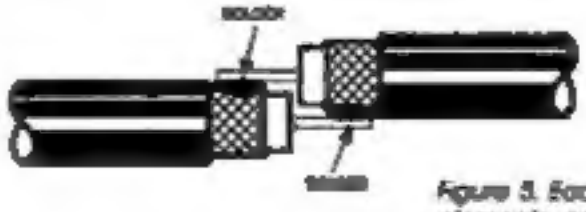

Figure 5. Each joint between the elements, and the joint at the feedpoint, is made like this.

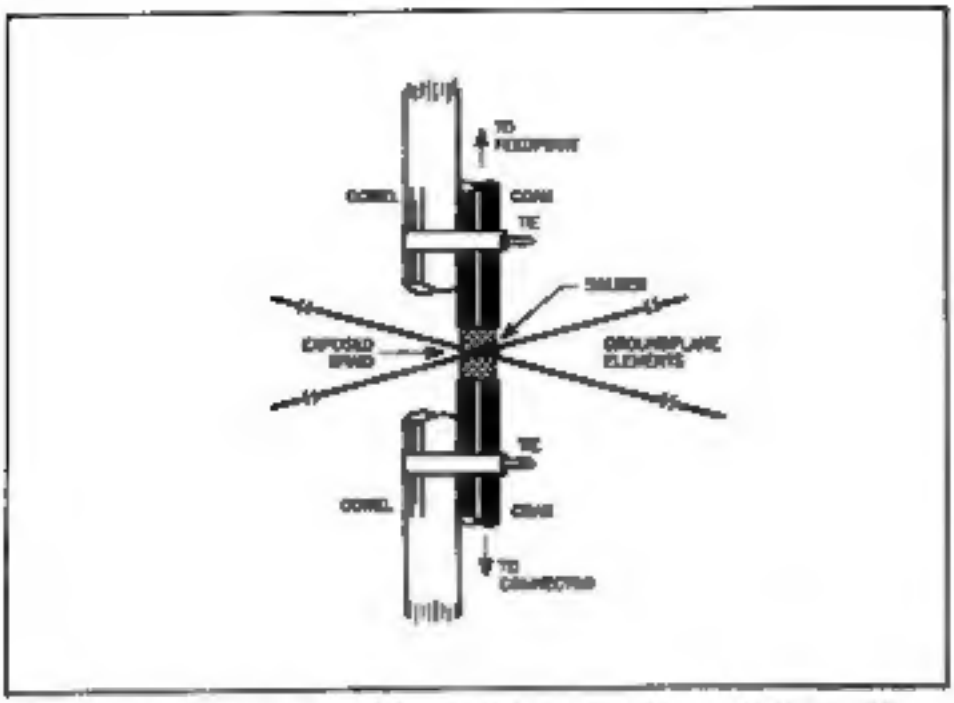

Figure 6. You make the groundplane in this manner. Be sure to thoroughly seal the area of the exposed braid, as described in the text.

joint to hold it securely to the dowel.

Now, temporarily tie the coax to the dowel near the exposed shield braid. This will secure it while you attach the groundplane elements. Position each groundplane element on the exposed braid and solder them in place at right angles to each other. Take care to solder them properly but not to damage the coax, either (a hot iron with a spade tip is best for this).

13) When the joint is cool, take off the temporary ties and apply a little silicone sealant around the groundplane joint. While the silicone is still plastic, slip the two pieces of heatshrink tubing along to cover the groundplane joint and apply a blast of hot air. Afterwards, cover the joint thoroughly with silicone [redacted] (you don't want water getting into the coax).

14) Put ties around the dowel and coax, either side of the groundplane, then another tie a little below the groundplane to secure the flying lead, leaving a slack 'kink' in the cable so that any tension is taken by the bottom-most tie.

15) Last of all, put some sort of cap over the top end of the dowel and seal it to prevent it weathering. A damp dowel degrades the collinear's performance, so use a rubber furniture bung of the right size. Or, a short length of heatshrink tubing of the right diameter, tied off and shrunk in place.

That completes the construction. Now to erect it. As individual circumstances vary widely, I'll just give a few hints and tips.

The bottom end of the dowel can be clamped to the top of a mast using hose or muffler clamps that are tightened with a worm-drive mechanism. Use two clamps spaced apart a little to properly support the dowel.

The feedline from your collinear to your rig should be a good quality, low-loss coax. The large diameter 'half-inch' variety is readily available, and affordable. For these frequencies, though, it's better to pay more and get a cable with the lowest-loss. Belden 9913 is the best of the flexible half-inch cables around and it's stocked by Dick Smith Electronics. You're next best choice would be 'RG213 foam', which is also available from Dick Smith Electronics.

You must mount the collinear well clear of other vertical structures, particularly if they're metallic. The antenna described is readily mounted on a standard TV chimney mount, or even a barge-board mount.

PARTS LIST

Two metres of RG58CU (MIL-C-17F preferred)
500 mm of 9.5 or 12.7 mm diameter heatshrink
100 mm of 6.4 mm heatshrink
in-line coax connector to suit (BNC suggested)
600 mm of 18 gauge tinned copper wire or brazing rod
Two metre length of 12.7 mm or 19 mm diameter dowel
Five or six cable ties
Silicone sealant
Solder
Outdoor wood stain or linseed oil

TOOLS YOU'LL NEED

Sharp penknife or 'hobby' knife
Sharp, pointed sidecutters
Soldering iron, preferably temperature controlled
Small shifting spanner
Pair of needle-nose pliers

Performance

An eight element array like this has 9dB of gain over a dipole. Your 10 watt rig will sound like an 80 watt rig on a Slim Jim, or like a 100 watt rig on a groundplane – it's cheap gain! A transistor power amp to take your rig's output from 10W up to 80- or 100 watts will cost you $2 per watt, or more. So this collinear costs about one-tenth the price of a power amp. So, how much power will it take? As much as you're legally allowed to run 'up the stick.'

If you live in a valley and hope this antenna will 'get you out', expect the unexpected. It may make things worse because of its low radiation angle. The gain is achieved by compressing the vertical radiation angle. Try it. If you don't get the improvement expected, chop off the top four elements and try again. It sounds weird, but I know of one constructor who successfully performed this operation, to his surprise, but not mine!

I have made various versions of coaxial collinears over the years, for both temporary, permanent and portable applications. A portable collinear is easily made by lying or taping the coax elements and lead cable to a length of hemp rope. In use, the top end of the rope is tied off to something suitable, like a tree branch or other form of 'skyhook', and the bottom end is either tied down or weighted so that the array is held vertical. When not in use, just roll it up.

I've made four-element coax collinears for 2m, in both 'fixed' and portable versions, an eight-element centre-fed horizontal monster some 15 metres long for six metres, and UHF versions ranging from a four-element job for mobile use to a 16 element phallic symbol nearly four metres tall. ●